1. Calculate beta (β) for the solar wind:
   n = 10 cm^{-3} = 10^7 m^{-3}; v = 400 km/s = 4×10^5 m/s;
   m = 1.67×10^{-27} kg; B = 7 nT = 7×10^{-9} Tesla.

$$\beta = \frac{n\left(\frac{1}{2}\ mv^2\right)}{B^2/2\mu_o} = \frac{10^7 \bullet 0.5 \bullet 1.67\times10^{-27} \bullet 16\times10^{10}}{49\times10^{-18}/8\pi\times10^{-7}} = \frac{1.34\times10^{-9}}{1.95\times10^{-11}} = 68.5$$

- the plasma pressure dominates

2. We need to know the temperature of the stellar plasma before we can answer this question.

3. $\tan\Psi = \dfrac{\omega r}{v}$ is the formula. For 400 km/s solar wind, the RHS equals 1, so ψ = 45°. Double v, tan Ψ drops to 0.5, Ψ drops to 26.6°. This can happen.

4. mostly a matter of opinion, I suppose. Not enough information to really say.

5. Average kinetic energy is: $\frac{1}{2}mv^2_{thermal} = \frac{3}{2}kT$, $v_{thermal} = \sqrt{3kT/m}$

ions:	electrons:
$v_{thermal} = \sqrt{3\bullet1.6\times10^{-19}\bullet7/1.67\times10^{-27}}$ $= \sqrt{2.01\times10^9} = 4.5\times10^4\ \frac{m}{s} = 45\ \frac{km}{s}$	$v_{thermal} = \sqrt{3\bullet1.6\times10^{-19}\bullet10/9.1\times10^{-31}}$ $= \sqrt{5.27\times10^{12}} = 2.3\times10^6\ \frac{m}{s} = 2300\ \frac{km}{s}$
Mach Number = $\dfrac{v_{wind}}{v_{thermal}} = \dfrac{400\ \frac{km}{s}}{45\ \frac{km}{s}} = 8.9$	Mach Number = $\dfrac{v_{wind}}{v_{thermal}} = \dfrac{400\ \frac{km}{s}}{2300\ \frac{km}{s}} = 0.17$

Problem 7.

The assignment solution ought to look something like the following, for the given parameters. The point is that the product of the exponentially decaying barometric relation, times the area of the surface (r^2), can produce a velocity which is increasing, and can increase to a Mach number above 1. The second figure shows a family of curves, normalized by the appropriate Mach number for each temperature. The primary limitation in this simple look at the acceleration of the solar wind is the neglect of the effect of the plasma pressure on the expansion.

$$n(r) = n_o \exp\left[\frac{G\,M_\circ m_H}{kT\ R_\circ}\left(\frac{1}{r} - \frac{1}{r_o}\right)\right]$$

m_H = $1.67 \times 10^{-27;}$ G = 6.67×10^{-11} Newton-m^2/kg^2

$n_o = \rho_o/m_H = \dfrac{10^{-7}\ \frac{kg}{m^3}}{1.67\times10^{-27}} = 6\times10^{19}\ \frac{protons}{m^3}$; r_o = 1 solar radius;

T is 1.0×10^6 - 2.0×10^6; $k = 1.38\times10^{-23}$ J/K

$M_o = 1.989\times10^{30}$ kg; $R_o = 6.96\times10^8$ m

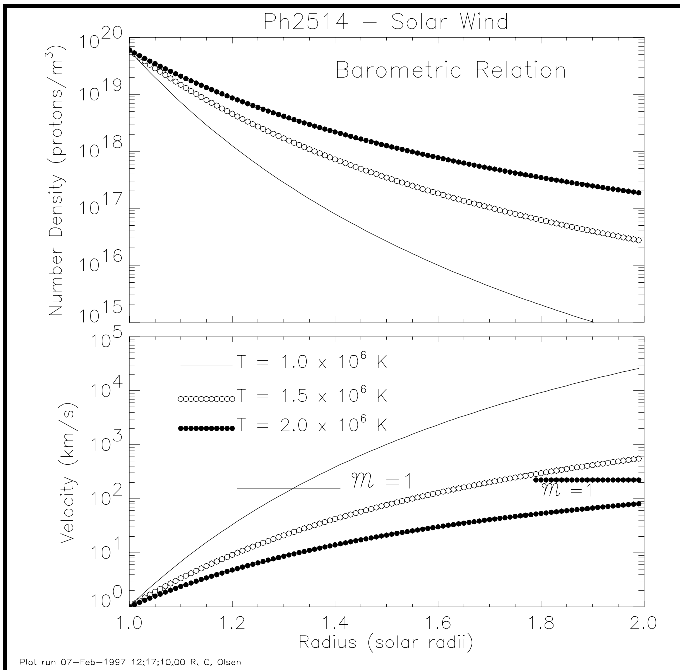
$$n(r) = n_o \exp\left[\frac{23.07}{T(\text{millions of degrees})}\left(\frac{1}{r} - \frac{1}{r_o}\right)\right]$$

Flux through the (Gaussian) surface $(n \bullet v \bullet \text{Area})$ is the conserved quantity:

$n_o \bullet v_o \bullet r_o^2 = n \bullet v \bullet r^2$. Taking $r_o = 1$

$$n_o v_o = n_o \exp\left[\frac{G M_o m_H}{kT\ R_o}\left(\frac{1}{r} - \frac{1}{r_o}\right)\right] v r^2$$

$$\frac{v}{v_o} = \frac{1}{r^2}\exp\left[\frac{23.07}{T}\left(1 - \frac{1}{r}\right)\right]$$



One question you might ask is what happens beyond r = 2 solar radii in this model. The answer is modified slightly - you can see you really have to go up to 2.25 million degrees before the solar wind will stabilize at a subsonic value.